The pH change in rhizosphere of *Pinus koraiensis* seedlings as affected by different nitrogen sources and its effect on phosphorus availability

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Abstract: Root mat method described by Kuchenbuch and Jungk was used to study the rhizosphere processes. The experiment was carried out on two years old *Pinus koraiensis* seedlings. Soil samples collected from the upper 20-cm soil layer in Changbai Mountain were treated with three different forms of nitrogen fertilizers: NO_3^--N, NH_4^+-N and NH_4NO_3. The results showed that the soil pH and available P near the roots were all lower than in the bulk soil in control treatment. NH_4^+-N application greatly decreased the soil pH near the roots compared to the control treatment and promoted the absorption of phosphorus, which led to a more remarkable depletion region of available P. On the contrary, the rhizosphere soil pH was higher than in the bulk soil in treatments with NO_3^--N and retarded the P absorption, which led to a nearly equal available P contents to the bulk soil. In treatment with NH_4NO_3, the rhizosphere soil pH was only a little lower than that in the control treatment and its effects on P absorption is mediate between the treatments with NH_4^+-N and NO_3^--N.

Keywords: Nitrogen sources; Rhizosphere pH; Available P
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Introduction

The soil conditions at the root-soil interface are considerably different from those at a distance from the root and thereafter influence the plant growth more obviously. For this reason, many researchers take interest in studying the characteristics of this zone, relative to those of the bulk soil (Marschner *et al.* 1987; Gahoonia *et al.* 1992a, 1992b; Hedley *et al.* 1994; Chen *et al.* 2001a, 2001b). pH changes in the rhizosphere have important influences on availability or solubility of nutrients (Marschner *et al.*, 1986). For example, acidification of the rhizosphere soil associated with a predominant NH_4^+-N uptake compared to NO_3^--N resulted in increased availability and uptake of sparingly soluble nutrient such as P from rock phosphate (Thomson *et al.* 1993). The objective of this study is to evaluate the effects of nitrogen source on the available P contents in the rhizosphere of *Pinus koraiensis* in relation to the rhizosphere soil pH changes.

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Materials and methods

The soil samples used in this experiment were collected from Changbai Mountain Research Station of Ecosystem of Chinese Academy of Sciences, belonging to dark brown forest soil, at the upper 20-cm soil layer after the litter was removed. The soil was air-dried, passed through a 2 mm sieve to remove stones and dead fine roots. The general physical and chemical properties of the soil were analyzed by the standard method issued by the State Standard Bureau. Then the soil was amended with three different forms of nitrogen fertilizers: NO_3^- as $Ca(NO_3)_2$, NH_4^+ as NH_4Cl and NH_4NO_3 at the rate of 100 mg $N \cdot kg^{-1}$ oven dry soil. A control experiment without nitrogen was included at the same time. All nutrients were added as solutions and were completely mixed with the soil. The nitrification inhibitor dicyandiamide (DCD) was mixed with the soil in all treatments at a rate of 50 $mg \cdot kg^{-1}$ in order to prevent conversion of NH_4^+ to NO_3^-.

Rhizosphere study method described by Kuchenbuch and Jungk (1982) was used to study the rhizosphere processes. In each pot the whole soil was divided into two parts by a 30-μm pore-diameter polyester mesh. The experiment was carried out with two years old *Pinus koraiensis* seedlings. The seedling roots in the upper soil striking the polyester mesh were unable to penetrate the mesh and

grew horizontally along the mesh forming a root mat. The soil below the polyester mesh represented the rhizosphere and the zone of transition demarcating the bulk soil. Every treatment was replicated five times and arranged in a randomized complete block design in a greenhouse. The soil was kept at about 80% field capacity by regular watering with distilled water.

At the end of 12 weeks, the soils bellow the polyester mesh were kept in the refrigerator for 24 h and then sliced into 1 mm thin sections with a microtome. The soil sections of the same distance from the root surface for the same treatment were mixed together to make sure the samples to be analyzed were sufficient. Finally, the soil sections were analyzed for pH and P. All analyses were carried out by standard method issued by the State Standard Bureau.

Results and discussions

Effects of different N forms on rhizosphere pH

The experimental result of the soil pH at different distance from the root surface was given in Fig. 1. In the control treatment, the rhizosphere soil pH was only slightly lower than that of the bulk soil. One of the main reasons of this phenomenon may be that the roots can excrete some organic acids. Another reason may be that the root and the microbes in the rhizosphere can release carbon dioxide into the rhizosphere by respiratory activities.

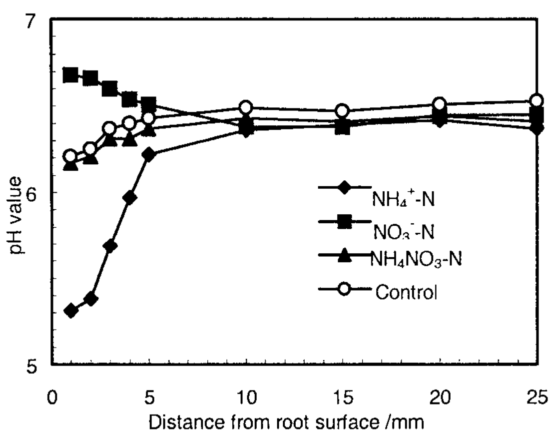

Fig. 1 pH change at different distances from root surface as affected by different N sources

In general, NH_4^+ application greatly decreased the soil pH near the roots of the *Pinus koraiensis* seedlings compared to the control treatment. The extension of decrease in pH depended on the distance from the root surface. The nearer to the root surface it was, the lower the rhizosphere pH was. When the distance was more than 4 mm the pH value was almost equal to the bulk soil pH. On the contrary, in treatments with NO_3^-, the rhizosphere soil pH increased. However, the extension of increase was obviously lower than that of decrease in the NH_4^+ treatment. Soil pH value near the root decreased by 1.1 pH units when the ammonium was applied and increased only by 0.25 units. In treatment with NH_4NO_3, the rhizosphere soil pH was only a little lower than that in the control treatment. The result confirms that rhizosphere soil pH near plant roots might differ markedly from the bulk soil pH. The direction and degree of the changes mainly depends on source and level of the nitrogen applied. The form in which nitrogen is absorbed by plant largely determines the acidifying or alkalizing effects of plant rhizosphere. From ionic balance studies, when being applied mainly with NH_4^+-N, the plant accumulate more positive charges in it and can always excrete H^+ to keep the charge balance in it. On the contrary, when being given mainly with NO_3^--N, the plant accumulates more minus charges in it and can always give rise to OH^- or HCO_3^- excretion. It can be concluded that ammonium nutrition can always lead to H^+ excretion and decrease the rhizosphere pH, while nitrate nutrition can always give rise to OH^- or HCO_3^- excretion and increase the rhizosphere pH. The changed pH in the rhizosphere will certainly affect the availability of P and some other nutrient elements.

Effects of different N forms on P characteristics in rhizosphere

The available phosphorus concentrations near the root surface were markedly affected by the pH changes in the rhizosphere. In the control treatment, the available phosphorus concentrations near the root surface were lower than those in the bulk soil, and the nearer to the root surface the position was, the lower the available phosphorus content was than in the bulk soil. There existed a lowest depletion rate at the point 1 mm away from the root surface (Fig. 2).

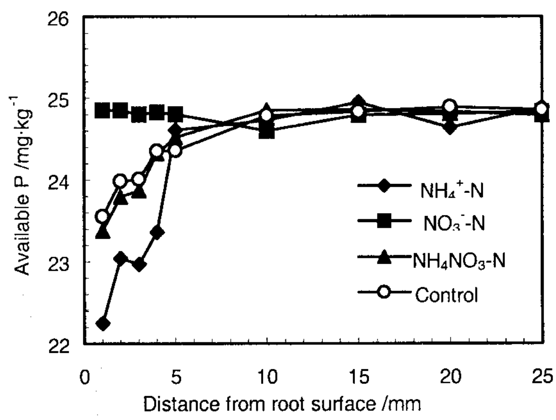

Fig. 2 Available P contents at different distances from the root surface as affected by different pH changes induced by different nitrogen sources

The available phosphorus content in the soil was considerably affected by the soil pH. The rhizosphere pH value of the *Pinus koraiensis* seedlings changed in response to the application of different N fertilizers. In all the treatments, the rhizosphere soil pH decreased or increased in com-

parison to the bulk soil, which may have different effects on the mobilization of the rhizosphere phosphate. In the NH_4^+-N treatment, the lower pH accelerated the mobilization of the phosphate compared with the control treatment and promoted the phosphorus absorption, which led to a more remarkable depletion region of phosphorus compared to the control treatment. In the NO_3^--N treatment, the increased rhizosphere soil pH may retard the mobilization of the phosphate and decrease the phosphorus absorption, which led to nearly equal phosphorus content to the bulk soil. In the NH_4NO_3 treatment, the pH changed little compared to the control treatment and the available phosphorus content was also nearly equal to that in the control treatment.

Conclusion

Different nitrogen sources had different effects on rhizosphere pH and the changed pH affected the absorption of phosphorus. NH_4^+ application greatly decreased the soil pH near the root surface of the *Pinus koraiensis* seedlings and the lower pH promoted the mobilization of the phosphate and the phosphorus absorption compared to the control treatment. On the contrary, in treatments with NO_3^-, the rhizosphere soil pH increased. However, the extension of increase is obviously lower than that of decrease in the NH_4^+ treatment. The increased rhizosphere soil pH retarded the mobilization of the phosphate and decreased the phosphorus absorption. In treatment with NH_4NO_3, the rhizosphere soil pH was only a little lower than that in the control treatment and the available phosphorus content was also nearly equal to that in the control treatment.

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